PB81-192080

East Gallatin River, Montana Macroinvertebrate Distribution and Water Analysis 1973-1974

Montana State Univ.
Bozeman

Prepared for

Environmental Research Lab.
Duluth, MN

1976

U.S. Department of Commerce
National Technical Information Service
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5. PRESENT TITLE: East Gallatin River, Montana: Macroinvertebrate Distribution and Water Analysis 1973-1974

a. TECHNICAL INFORMATION PLAN TITLE AND REFERENCE

6. AUTHOR, ORGANIZATION, AND ADDRESS
Luedtke, R. J., R. C. Russo, and R. V. Thurston, Fisheries Bioassay Laboratory, Montana State University, Bozeman, Montana 59715

EPA PROJECT DOCUMENTATION

7. SERIES	8. REPORT DATE	9. CONTRACT/GRANT/IAG NUMBER
EPA-600/J-76-106	Jour. Att. April 1981	

10. TYPE OF MATERIAL (✓ one)
SPECIFY (WHERE NECESSARY)

- ☐ RESEARCH REPORT
- ☐ PROJECT REPORT AND PROJECT SUMMARY
- ☒ JOURNAL PUBLICATION
- ☐ UNPUBLISHED REPORT
- ☐ AUDIO VISUAL
- ☐ MEETING/PUBLICATION
- ☐ APPLICATIONS GUIDE
- ☐ SUMMARY/SYNTHESIS
- ☐ RESPONSE REPORT

11. PROJECT OFFICER/IN-HOUSE AUTHOR

a. SIGNATURE	b. DATE
Kenneth E. F. Hokanson	3/16/81

c. TYPED NAME AND ADDRESS	d. FTS TELEPHONE NO.
Kenneth E. F. Hokanson, U.S. EPA, Monticello Ecological Research Station, Monticello, Minnesota 55362	787-3332

12. TECHNICAL INFORMATION (PROGRAM) MANAGER

a. SIGNATURE	b. DATE
John D. Treasley for	23 March 1981

c. TYPED NAME AND ADDRESS	d. FTS TELEPHONE NO.
Evelyn P. Hunt, U.S. EPA, Environmental Research Laboratory-Duluth, 6201 Congdon Boulevard, Duluth, Minnesota 55804	783-9586

13. COMMENTS

PUBLISHED: Proceedings of the Montana Academy of Sciences 36: 21-36 (1976)

Case File PB81 192080

EPA-350/(Cin)(8-80)

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/J-76-106	2. Journal Article
3 PB81-192090	
4. TITLE AND SUBTITLE: East Gallatin River, Montana: Macroinvertebrate Distribution and Water Analysis 1973-1974	5. REPORT DATE: April 1981
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Luedtke, R. J., R. C. Russo, and R. V. Thurston	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Fisheries Bioassay Laboratory, Montana State University, Bozeman, Montana 59715	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO. R800861
12. SPONSORING AGENCY NAME AND ADDRESS: U.S. Environmental Protection Agency, Environmental Research Laboratory-Duluth, Monticello Ecological Research Station, Monticello, Minnesota 55362	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE EPA-600/03

15. SUPPLEMENTARY NOTES
Proceedings of the Montana Academy of Sciences 36: 21-36 (1976)

16. ABSTRACT

Macroinvertebrate samples from seven stations and water chemistry samples from 10 stations in the East Gallatin River, Montana, were collected on thirteen dates throughout the year between June 1973 and August 1974. The stations were selected to cover a stretch of the river both above and below the City of Bozeman sewage treatment plant. Marked changes in the macroinvertebrate populations were observed in the region immediately downstream from the sewage outfall. Recovery, in terms of increasing numbers of species and total numbers of clean-water forms and decreasing numbers of tolerant forms, appeared to be complete with 15-20 km below the outfall. Several species diversity indices were calculated but failed to be illustrative of the observed changes in the benthic insect community. Concentrations of a number of the chemical species measured showed a marked increase immediately below the sewage outfall; NH_3-N and PO_4-P showed the greatest increase (five- to seven-fold). These higher concentrations gradually diminished until at ~50 km downstream they were comparable to levels above the sewage outfall. With the exception of NO_2-N, none of the variables measured reached concentrations generally considered to be acutely toxic to fishes or aquatic macroinvertebrates.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

PRODUCT OF:
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

18. DISTRIBUTION STATEMENT: RELEASE TO PUBLIC	19. SECURITY CLASS (This Report): UNCLASSIFIED	21. NO. OF PAGES: 18
	20. SECURITY CLASS (This page): UNCLASSIFIED	22. PRICE

EPA-600/J-76-106
Journal Article

Proceedings of the Montana Academy of Sciences 36: 21-36, 1976

EAST GALLATIN RIVER, MONTANA: MACROINVERTEBRATE DISTRIBUTION AND WATER ANALYSIS 1973-1974

Robert J. Luedtke, Rosemarie C. Russo,
and Robert V. Thurston

INTRODUCTION

The East Gallatin River begins at the confluence of Bear and Rocky Creeks, east of Bozeman, Montana. It flows northwesterly through the Gallatin Valley for approximately 70 kilometers before joining the Gallatin River, north of Manhattan. The Gallatin is one of three rivers which join to form the Missouri River at Three Forks, Montana.

The East Gallatin drainage area is approximately 640 square miles (1660 km^2). The average discharge between 1939 and 1961 (measured approximately 6 km upstream from the Bozeman sewage treatment plant) was 85 cfs (2.4 m^3/sec); the maximum recorded discharge was 1230 cfs (35 m^3/sec) in June 1953, and the minimum was 12 cfs (0.34 m^3/sec) in December 1944 and March 1955 (16).

The principal point pollution source to the East Gallatin River is effluent from the Bozeman sewage treatment plant. Other sources include agricultural runoff, domestic sewage seepage, fish culture and industrial wastes.

Until December, 1970, Bozeman sewage was processed at a primary treatment plant which discharged into the East Gallatin approximately 1 km below the East Gallatin--Sourdough Creek confluence. This plant was replaced by a secondary treatment plant located 7 km downstream. The new plant began partial operation in December, 1970, and by August, 1971, was handling the total city discharge, with approximately 80 percent of the discharge receiving secondary treatment.

Avery (2) studied the effects of effluent from the original plant on the macroinvertebrate community of the East Gallatin River. Glorvigen (3) conducted a similar study during the transition from primary to secondary treatment (April, 1970--September, 1971). Both reported significant reductions in clean-water macroinvertebrate forms for several kilometers downstream from the sewage outfall. Glorvigen also reported that there appeared to be no detrimental effects on the invertebrate fauna approximately 6 km below the new sewage outfall. A discussion of water quality and a review of several studies on the East Gallatin is presented by Stuart, et al. (16). They found that average concentrations of nitrate, ammonia and orthophosphate showed an increase in the region below the new sewage outfall.

METHODS AND MATERIALS

Macroinvertebrates

Ten benthos sampling stations were established in June, 1973 (Figure 1). During August, Stations 1, 9, and 12B were

Figure 1. East Gallatin River Sampling Stations.

added, but were later eliminated along with Stations 4, 5, and 8A. Preliminary examination of benthos samples showed that the remaining seven stations were adequate for that section of the river where the macroinvertebrate community was affected by the sewage discharge.

Samples were collected from riffles which had small to medium (6-15 cm) cobble and water velocity ranging from 45 to 90 cm/sec, measured with a Gurley 625-F current meter. A modified Hess sampler (17) was used to obtain 0.28 m^2 samples from each station on twelve dates between June, 1973 and August, 1974. Organisms were identified to the species level where feasible; certain identifications were confirmed by recognized

authorities. Many Plecoptera and Ephemeroptera were reared to the adult stage to facilitate positive species determinations. Species diversity indices by Margalef (7), Simpson (13), Lloyd and Ghelardi (5), and Patten (9) as modified by Hamilton (4), were used in analyses of count data.

Water Chemistry

Thirteen water chemistry sampling stations were initially established (Figure 1). The number of stations was subsequently increased immediately downstream from the Bozeman sewage treatment plant, where there was a marked change in the water quality and aquatic biota. The number of stations was then reduced along the upper and lower reaches of the river where little change occurred.

Samples collected in May-July, 1973, were filtered (0.45 μ filter) for ammonia, nitrate and nitrite analyses. All other 1973 samples and the January-March, 1974, samples were not filtered. A portion of each sample collected from June-December, 1974, was filtered for ammonia, nitrate, nitrite, and trace metal analyses. Samples were preserved with nitric acid for subsequent trace metal analysis.

Temperature was measured either with a Taylor field thermometer or a YSI Model 33 S.C.T. meter; specific equivalent conductance was determined with the meter, and values were corrected to 25°C. Measurement of pH was made with Beckman Chem-Mate or Phasar-I meters. Fluoride was determined using an Orion 407 specific ion meter and fluoride electrode. Iron and zinc were determined using a Varian 1100 flame atomic absorption (AA) spectrophotometer; copper and cadmium were determined using a Varian AA-5 spectrophotometer equipped with a Woodriff furnace (18, 19) for flameless AA. Nitrite was determined by the method described in Strickland and Parsons (15). Dissolved oxygen was determined using either a YSI 54-RC meter or the azide modification of the iodometric method (1), with phenylarsine oxide substituted for sodium thiosulfate. All other chemical analyses were performed according to procedures described in APHA (1), and all colorimetric measurements were made using a Varian 635 uv-vis spectrophotometer.

RESULTS

Results for species diversity, total numbers of species and total numbers of individuals are presented in Tables I-III and Figure 2. A species checklist, with frequency of occurrence and relative abundance, is reported in Table IV. Values reported in Tables I-IV are mean values of all samples collected at each station (12 samples for Stations 6-7B, 7E, 8B; 11 samples for 7D; 10 samples for 7C). Raw data counts for each sampling date are available in a project report (6).

Results of chemical analyses are summarized in Table V. Data for Stations 5-7A, 10, and 12A are for 16 samples at each

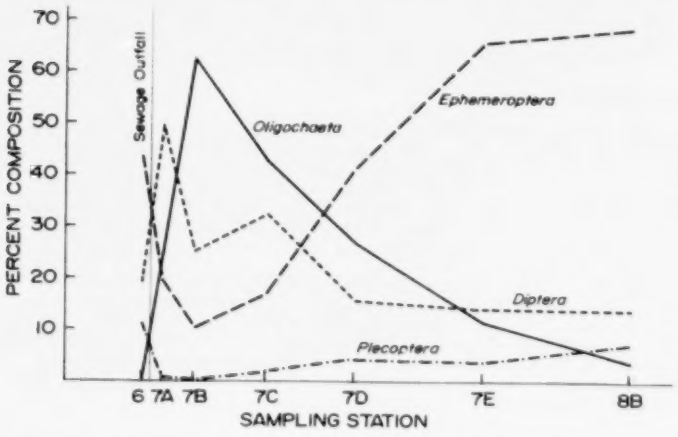

Figure 2. Diptera, Ephemeroptera, Plecoptera and Oligochaeta Composition in Percent of Total Numbers of Macroinvertebrates

station; Stations 7B, D, E and 8B had 12 samples, Station 7C had 11. Hardness determinations were averaged from 11 samples (10 samples at 7C). Trace element analyses are reported for 15 samples from Stations 5-7A, 10, 12A; for 11 samples from 7B, D, E and 8B; for 10 samples from 7C. The seemingly anomalously high iron concentrations were obtained on unfiltered samples. Although not included in Table V, a small number of fluoride analyses were performed at each station; the average values found were in the range of 0.18-0.26 mg/l. F^-. A complete tabulation of water chemistry analyses for each sampling date is available in project reports (10, 11), which also contain data for selected tributaries.

DISCUSSION

Marked changes in the macroinvertebrate populations were observed in the region immediately downstream from the sewage outfall point. Numbers of species and total numbers of clean-water forms (e.g., the mayflies *Baetis parvus* Dodds, *Ephemerella grandis* McDunnough; the stoneflies *Pteronarcella badia* (Hagen), *Isoperla mormona* Banks; and the caddisflies *Brachycentrus* sp. and *Hydropsyche* sp.) decreased, whereas tolerant forms (e.g., the dipterans *Athenix variegata*, *Psychoda* sp., and Oligochaeta) increased substantially. As a group, the stoneflies were most drastically affected by the sewage effluent, as

Table I. Diversity* and Biotic Index Values, East Gallatin River (Montana), June 1973 - August 1974
(Values given are means, with ranges in parentheses)

Sampling Stations	Shannon Index (4, 9)	Shannon's Redundancy (4, 9)	Equitability (5)	Margalef Index (7)	Simpson Index (13)
EG-6	2.60 (1.95-3.02)	0.43 (0.33-0.53)	0.42 (0.26-0.65)	3.01 (2.16-3.71)	0.26 (0.19-0.46)
EG-7A	2.49 (1.53-3.55)	0.43 (0.22-0.73)	0.65 (0.36-1.06)	2.58 (1.63-3.83)	0.28 (0.09-0.48)
EG-7B	2.60 (1.82-3.14)	0.35 (0.14-0.50)	0.75 (0.53-1.22)	2.40 (1.62-3.29)	0.23 (0.11-0.44)
EG-7C	2.98 (2.21-3.42)	0.34 (0.14-0.62)	0.77 (0.35-1.08)	3.05 (2.45-3.72)	0.17 (0.10-0.33)
EG-7D	2.58 (1.69-3.31)	0.43 (0.18-0.62)	0.48 (0.25-1.00)	2.94 (2.13-4.20)	0.26 (0.16-0.46)
EG-7E	2.03 (0.92-3.35)	0.54 (0.31-0.71)	0.33 (0.16-0.58)	2.47 (0.85-3.62)	0.39 (0.14-0.66)
EG-8B	2.24 (0.74-3.05)	0.52 (0.39-0.85)	0.33 (0.18-0.48)	2.72 (1.21-4.01)	0.35 (0.20-0.80)

*Diversity values based on insect counts excluding Chironomidae.

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Table II. Numbers of Aquatic Insect Species per Square Meter, East Gallatin River (Montana), June 1973 - August 1974
(Values given are means, with ranges in parentheses)

Sampling Stations	Aquatic Insect Species*					
	Ephem.	Plec.	Trich.	Cole.	Dipt.	Mean Totals
EG-6	6.8 (4-12)	5.0 (2-9)	4.4 (3-7)	1.7 (1-3)	3.2 (2-4)	21.1
EG-7A	3.6 (2-9)	1.5 (0-5)	2.4 (1-4)	0.9 (0-2)	4.3 (1-6)	12.7
EG-7B	4.1 (1-10)	1.4 (0-4)	2.0 (1-4)	1.2 (0-2)	3.7 (1-6)	12.4
EG-7C	5.5 (3-9)	2.3 (0-5)	3.0 (2-4)	1.3 (0-2)	3.8 (1-6)	15.9
EG-7D	6.3 (3-8)	3.5 (0-7)	3.8 (1-6)	1.9 (0-4)	4.2 (0-8)	19.7
EG-7E	7.0 (3-11)	3.7 (0-7)	3.0 (1-5)	1.1 (0-2)	3.8 (0-6)	18.6
EG-8B	7.7 (3-13)	4.8 (0-9)	3.8 (1-6)	1.0 (0-2)	4.2 (2-7)	21.5

*Ephem.=Ephemeroptera; Plec.=Plecoptera; Trich.=Trichoptera; Cole.=Coleoptera; Dipt.=Diptera (exclusive of Chironomidae).

Table III. Total Numbers of Aquatic Macroinvertebrates per Square Meter, East Gallatin River (Montana), June 1973 - August 1974 (Values given are means, with ranges in parentheses)

Sampling Stations	Macroinvertebrates*								
	Ephem.	Plec.	Trich.	Cole.	Dipt.	Oligo.	Gastr.	Hirud.	Isop.
EG-6	461 (113-895)	123 (16-268)	314 (6-837)	17 (0-40)	209 (8-355)	3 (0-7)	1 (0-2)	<1 (0-1)	<1 (0-1)
EG-7A	88 (3-437)	3 (0-20)	19 (2-60)	4 (0-11)	294 (4-957)	121 (14-272)	--	--	<1 (0-2)
EG-7B	92 (6-227)	4 (0-23)	11 (1-29)	9 (0-53)	285 (3-894)	973 (17-2160)	--	--	--
EG-7C	164 (14-746)	18 (0-152)	45 (3-316)	11 (0-34)	282 (3-1315)	273 (28-481)	--	--	--
EG-7D	554 (39-1138)	63 (0-176)	150 (1-442)	7 (0-18)	211 (3-525)	293 (17-1299)	1 (0-9)	<1 (0-2)	--
EG-7E	1103 (111-2369)	89 (0-240)	113 (1-264)	4 (0-11)	327 (5-1014)	169 (19-393)	3 (0-10)	<1 (0-2)	--
EG-8B	1640 (136-4556)	203 (0-625)	160 (2-565)	2 (0-4)	346 (7-704)	38 (2-162)	5 (0-21)	1 (0-2)	1 (0-2)

*Ephem.=Ephemeroptera; Plec.=Plecoptera; Trich.=Trichoptera; Cole.=Coleoptera; Dipt.=Diptera; Oligo.=Oligochaeta; Gastr.=Gastropoda; Hirud.=Hirudinea; Isop.=Isopoda.

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Table IV. Checklist, Frequency of Occurrence[1], and Relative Abundance[2] of Aquatic Macroinvertebrates, East Gallatin River, June 1973 - August 1974

	Benthos Sampling Stations						
	6	7A	7B	7C	7D	7E	8B
Ephemeroptera							
Baetidae							
Baetis parvus Dodds	100-A	83-P	50-P	80-N	100-A	100-A	100-A
Baetis alexanderi n. sp. Edmunds and Jensen	42-N	17-R	17-P	40-N	73-N	67-A	58-A
Ephemerellidae							
Ephemerella (Drunella) doddsi Needham	--	--	--	--	9-R	--	--
E. (Drunella) flavilinea McDunnough	25-R	25-R	17-R	30-R	18-R	8-R	--
E. (Drunella) grandis ingens McDunnough	83-P	25-C	83-P	80-P	82-P	67-P	75-P
E. (Timpanoga) hecuba hecuba Eaton	17-R	25-P	17-R	--	--	25-R	17-R
E. (Caudatella) heterocaudata heterocaudata McDunnough	8-R	--	8-R	20-R	--	--	--
E. (Ephemerella) inermis Eaton	83-A	67-C	75-C	100-P	73-N	75-A	92-A
E. (Attenuatella) margarita Needham	25-P	8-P	8-R	10-R	27-R	33-R	33-R
E. (Serratella) tibialis McDunnough	25-P	--	--	30-R	27-R	17-R	25-R
Heptageniidae							
Cinygmula sp.	25-P	17-P	17-P	10-R	36-R	8-R	8-R
Epeorus (Iron) longimanus (Eaton)	8-R	--	--	--	--	8-R	8-R
Heptagenia criddlei McDunnough	33-P	8-P	25-C	20-P	27-P	42-C	50-N
Heptagenia sp. nr. *simpliciodes* McDunnough	42-P	25-C	25-C	30-P	45-P	50-C	75-N
Rhithrogena sp. nr. *morrisoni* (Banks)	75-P	25-R	8-R	40-R	73-P	83-C	75-A
Leptophlebiidae							
Choroterpes sp.	--	--	--	--	--	--	8-R
Paraleptophlebia bicornuta (McDunnough)	8-R	--	--	--	--	25-R	25-R
P. debilis (Walker)	25-C	--	--	--	--	--	25-R
P. heteronea (McDunnough)	25-R	--	--	--	--	17-R	25-R
Tricorythidae							
Tricorythodes minutus Traver	42-N	50-N	50-N	60-C	64-A	67-A	67-A
Plecoptera							
Chloroperlidae							
Alloperla (Triznaka) signata (Banks)	58-P	25-R	33-R	60-R	45-R	50-R	50-P

Plecoptera (cont'd)							
Nemouridae							
Nemoura (Prostoia) besametsa Ricker	8-R	--	--	--	9-R	--	8-R
Nemoura (Zapada) cinctipes Banks	25-R	--	--	30-R	36-R	33-R	42-R
Leuctra sp.	8-R	--	--	--	--	--	--
Capnia (Capnia) confusa Claassen	17-R	17-R	8-R	10-R	8-R	--	8-R
Brachyptera (Taenionema) pacifica (Banks)	8-R	--	--	10-R	--	17-R	17-R
Perlidae							
Acroneuria (Hesperoperla) pacifica Banks	25-R	--	--	10-R	18-R	17-R	8-R
Perlodidae							
Arcynopteryx (Skwala) parallela (Frison)	67-C	--	--	10-C	54-P	58-P	58-P
Isogenus (Isogenoides) elongatus Hagen	17-R	8-R	--	--	--	--	42-R
Isoperla fulva Claassen	75-C	25-R	33-R	30-R	42-C	67-N	67-A
Isoperla mormona Banks	75-C	33-R	33-R	20-R	45-P	50-C	67-N
Pteronarcidae							
Pteronarcella badia (Hagen)	92-N	42-R	25-R	30-C	82-N	75-C	92-N
Pteronarcys californica Newport	17-R	--	8-R	10-R	9-R	--	--
Trichoptera							
Brachycentridae							
Amiocentrus aspilus (Ross)	25-R	8-P	17-R	20-R	18-R	25-R	25-R
Brachycentrus sp.	100-P	67-R	50-R	80-P	82-C	67-R	83-P
Micrasema sp.	8-R	--	--	--	--	--	--
Glossosomatidae							
Agapetus sp.	8-R	--	--	10-R	--	--	17-R
Helicopsychidae							
Helicopsyche sp.	--	8-R	--	--	9-R	8-R	42-P
Hydropsychidae							
Arctopsyche grandis (Banks)	67-R	8-R	8-R	20-R	55-R	17-R	--
Cheumatopsyche sp.	42-R	25-R	8-R	10-P	55-P	58-P	67-R
Hydropsyche sp.	100-A	100-P	83-P	100-N	91-A	92-N	100-A
Hydroptilidae							
Ochrotrichia sp.	8-R	--	--	--	18-R	--	--
Lepidostomatidae							
Lepidostoma sp.	42-R	25-R	8-R	30-R	36-P	33-P	50-N
Limnephilidae							
Hesperophylax sp.	--	--	--	--	9-R	--	--

Table IV. (cont'd)

	Benthos Sampling Stations						
	6	7A	7B	7C	7D	7E	8B
Trichoptera (cont'd)							
Rhyacophilidae							
Rhyacophila angelita Banks	--	--	--	10-R	--	--	--
R. coloradensis Banks	17-R	--	8-R	10-R	--	--	8-R
Rhyacophila sp. A	25-R	--	17-R	10-R	--	--	--
Diptera							
Chironomidae	100-A	100-A	100-A	100-A	100-A	92-A	100-A
Empididae							
Chelifera sp.	17-R	75-R	50-R	50-P	55-R	42-P	33-R
Heleidae							
Palpomyia sp.	17-P	33-P	17-P	50-R	27-R	17-R	17-R
Psychodidae							
Psychoda sp.	--	25-R	8-R	--	--	--	--
Rhagionidae							
Atherix variegata Walker	75-R	75-P	83-C	70-P	82-P	75-P	75-P
Simuliidae							
Simulium sp.	33-N	42-P	50-P	40-P	64-C	92-P	58-C
Tabanidae							
Tabanus sp.	--	8-R	8-R	--	9-R	17-R	--
Tipulidae							
Antocha monticola Alexander	42-R	50-R	33-R	60-R	27-R	8-R	33-R
Dicranota sp.	--	17-R	17-R	10-R	8-R	--	25-R
Hexatoma sp.	83-P	50-R	25-R	60-R	73-P	67-R	83-P
Tipula sp.	42-P	58-R	75-P	70-P	73-P	67-P	75-C
Coleoptera							
Dytiscidae							
Deronectes sp.	--	8-R	--	--	27-R	--	17-R
Elmidae							
Lara sp.	8-R	--	--	--	27-R	8-R	--
Optioservus sp.	92-P	67-R	92-P	90-P	100-P	83-R	75-R
Zaitzevia parvula Horn	67-R	17-R	25-R	40-R	36-R	17-R	8-R
Haliplidae							
Haliplus sp.	--	--	--	--	9-R	--	--

Gastropoda	42-R	--	--	--	27-R	50-R	58-P
Hirudinea	8-R	--	--	--	18-R	25-R	42-R
Isopoda	8-R	17-R	--	--	9-R	8-R	33-R
Oligochaeta	67-R	100-A	100-A	100-A	100-A	100-A	100-C

[1] Frequency of Occurrence = $\frac{\text{no. of occurrences}}{\text{no. of samples}} \times 100$

[2] R: Rare (1-5), P: Present (6-20), C: Common (21-50), N: Numerous (51-100), A: Abundant (>100).
[Mean numbers of individuals per occurrence].

Table V. East Gallatin River
(Values given are means,

Sample Station	Temp. °C	D.O. mg/l	pH	S.E.C. µmhos	Alk. mg/l	Cadmium µg/l	Calcium mg/l	Chloride mg/l
5			8.25	369	179	0.04	51.0	1.7
	(0.0-	(6.8-	(8.10-	(249-	(127-	(0.01-	(38.5-	(0.5-
	14.3)	12.7)	8.50)	490)	206)	0.10)	59.5)	3.4)
6			8.28	366	184	0.03	52.3	2.0
	(0.0-	(7.0-	(8.10-	(260-	(130-	(0.01-	(38.6-	(0.2-
	15.8)	13.4)	8.65)	468)	215)	0.09)	61.9)	3.8)
7A			8.19	380	189	0.07	52.5	4.6
	(1.0-	(6.8-	(8.00-	(266-	(132-	(0.01-	(39.7-	(0.8-
	15.3)	12.7)	8.55)	533)	225)	0.16)	62.7)	10.4)
7B			8.23	398	197	0.04	54.5	5.1
	(1.0-	(7.0-	(8.01-	(321-	(163-	(0.02-	(46.0-	(1.8-
	16.8)	12.4)	8.55)	487)	227)	0.09)	62.7)	10.0)
7C			8.22	391	199	0.04	55.2	4.5
	(0.6-	(7.7-	(8.05-	(328-	(166-	(0.01-	(45.6-	(1.4-
	17.0)	12.6)	8.50)	500)	231)	0.07)	62.7)	6.8)
7D			8.28	385	196	0.03	55.0	4.2
	(0.0-	(8.1-	(8.05-	(322-	(166-	(0.02-	(46.4-	(1.3-
	18.0)	12.5)	8.50)	450)	225)	0.08)	62.3)	6.4)
7E			8.25	387	196	0.04	54.6	3.9
	(0.2-	(7.8-	(8.10-	(325-	(166-	(0.02-	(45.8-	(1.1-
	18.0)	11.9)	8.48)	430)	223)	0.06)	60.7)	5.9)
8B			8.38	381	195	0.03	53.9	4.2
	(0.0-	(8.4-	(8.15-	(325-	(165-	(0.02-	(45.6-	(0.6-
	20.0)	12.9)	8.70)	427)	223)	0.05)	60.2)	6.9)
10			8.23	374	191	0.05	53.8	3.2
	(2.2-	(7.7-	(8.10-	(258-	(127-	(0.02-	(38.1-	(0.9-
	17.5)	12.6)	8.55)	428)	221)	0.14)	63.5)	6.4)
12A			8.28	366	187	0.04	53.1	2.4
	(1.7-	(9.0-	(7.90-	(271-	(136-	(0.02-	(40.1-	(1.0-
	18.5)	13.2)	8.70)	422)	206)	0.14)	59.4)	3.2)

Chemical Analysis Summary, 1973 - 1974
with ranges in parentheses)

Copper mg/l	Hard-ness mg/l	Iron mg/l	NH_3-N mg/l	NO_2-N mg/l	NO_3-N mg/l	PO_4-P mg/l	Zinc mg/l
0.006 (<0.002-0.020)	197 (160-226)	0.55 (<0.07-3.97)	0.16 (0.00-0.55)	0.00 (0.00-0.04)	0.41 (0.05-0.72)	0.04 (0.01-0.10)	0.010 (<0.008-0.021)
0.006 (<0.002-0.021)	202 (163-230)	0.55 (<0.07-3.54)	0.18 (0.00-0.72)	0.00 (0.00-0.01)	0.41 (0.04-0.82)	0.04 (0.01-0.14)	0.012 (<0.008-0.020)
0.013 (0.003-0.023)	202 (165-229)	0.57 (<0.07-3.74)	1.13 (0.24-2.35)	0.02 (0.00-0.11)	0.48 (0.12-1.01)	0.28 (0.08-0.59)	0.017 (<0.009-0.038)
0.010 (0.003-0.019)	203 (168-228)	0.17 (<0.07-0.41)	1.05 (0.34-2.30)	0.02 (0.01-0.05)	0.46 (0.12-1.02)	0.26 (0.01-0.56)	0.011 (<0.009-0.021)
0.010 (0.002-0.024)	204 (168-227)	0.17 (<0.07-0.40)	0.82 (0.29-1.60)	0.02 (0.01-0.07)	0.45 (0.12-0.99)	0.22 (0.08-0.40)	0.013 (<0.010-0.021)
0.009 (0.004-0.017)	204 (167-230)	0.28 (<0.07-1.30)	0.63 (0.26-1.28)	0.02 (0.01-0.06)	0.47 (0.13-1.04)	0.20 (0.08-0.36)	0.011 (<0.008-0.016)
0.008 (0.002-0.017)	202 (165-226)	0.19 (<0.07-0.52)	0.54 (0.13-1.22)	0.03 (0.01-0.08)	0.48 (0.10-1.11)	0.24 (0.08-0.47)	0.012 (<0.008-0.020)
0.006 (0.002-0.010)	200 (165-224)	0.19 (<0.07-0.45)	0.51 (0.15-1.31)	0.03 (0.01-0.10)	0.55 (0.11-1.22)	0.29 (0.09-0.56)	0.011 (<0.008-0.019)
0.005 (<0.002-0.010)	202 (160-223)	0.71 (<0.07-4.42)	0.34 (0.12-0.96)	0.02 (0.01-0.06)	0.72 (0.26-1.30)	0.19 (0.07-0.37)	0.012 (<0.008-0.020)
0.004 (<0.002-0.012)	199 (165-215)	0.88 (<0.07-5.00)	0.24 (0.05-1.04)	0.01 (0.00-0.05)	0.57 (0.18-1.02)	0.10 (0.05-0.20)	0.012 (<0.008-0.024)

evidenced by greatly reduced numbers at Stations 7A-7E. Recovery, in terms of increasing numbers of species and total numbers of clean-water forms and decreasing numbers of tolerant forms, began at Station 7C and appeared to be complete by Station 8B. Extremely large numbers of mayflies and stoneflies at Station 8B is believed to reflect a "fertilization" effect, commonly associated with organic enrichment in aquatic ecosystems.

Several species diversity indices were calculated but failed to be illustrative of observed changes in the benthic insect community (Table I). High numbers of a few species (e.g., *Baetis parvus*, *B. alexanderi* and *Hydropsyche* sp.) resulted in low diversity values at control Station 6 even though the total number of species was high. Also, species diversity indices do not respond to changes in the species composition of a community, but only to total numbers of species and their relative abundances.

Just below the sewage outfall point, at Station 7A, the concentrations of a number of chemical species increase. Concentrations of NH_3-N and PO_4-P showed the greatest increase (five to seven times higher than found above the sewage outfall). These higher concentrations gradually diminish, and by Station 12A they are comparable to levels above the effluent input. The concentrations of Cl^- and Cu approximately double at 7A; these also diminish gradually and return to background levels at 12A. With the exception of NO_2-N, none of the concentrations reaches levels considered lethal to fishes or aquatic macroinvertebrates (8). For NO_2-N, the highest concentrations found approach that known to be toxic to rainbow trout (12). Also, the higher NH_3-N concentrations observed have been shown (14) to exhibit deleterious sublethal effects on rainbow trout.

Even though changes in macroinvertebrate community structure corresponded to changes in ammonia concentrations, other measured chemical parameters with corresponding changes cannot be ignored. In addition, other chemical species (e.g., chloramines), known to be toxic to aquatic organisms (no data available for the East Gallatin River), would presumably show an increase below the Bozeman sewage outfall. Preliminary 96-hour bioassay studies at Fisheries Bioassay Laboratory have shown that the ammonia concentrations observed in the East Gallatin are not lethal under laboratory conditions to nymphs of the mayflies *Ephemerella grandis* and *E. doddsi* and the stonefly *Pteronarcella badia*.

Additional acute and chronic laboratory bioassays on representative macroinvertebrates, especially using ammonia and chloramines as the toxicants, will be necessary before additional conclusions can be drawn from this study. Also, a subsequent study on the East Gallatin River should involve

instream bioassays of representative invertebrate species and more comprehensive chemical analyses of sewage, river water, and riverbed sediments, in order to identify and quantify all chemical species which are suspected to be toxic.

ACKNOWLEDGEMENT

This research was supported in part by the Water Quality Office of the U.S. Environmental Protection Agency under grant number R800861. The following persons confirmed our macroinvertebrate identifications: A. R. Gaufin, S. L. Jensen, C. D. Hynes, S. D. Smith, and G. B. Wiggins. R. A. Craig and C. M. Bennett performed many of the chemical analyses, and H. Snedigar rough-sorted most of the macroinvertebrate samples. D. M. Gillespie assisted in the initial stages of the research, and C. J. D. Brown reviewed the final manuscript.

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Address correspondence to Dr. Robert V. Thurston, Fisheries Bioassay Laboratory, Montana State University, Bozeman, Montana 59715